ON MAN'S CRANIAL FORM

TOGETHER WITH

SOME REMARKS ON THE ATTITUDE OF THE MEDICAL PROFESSION TOWARDS ANTHROPOLOGY

BY

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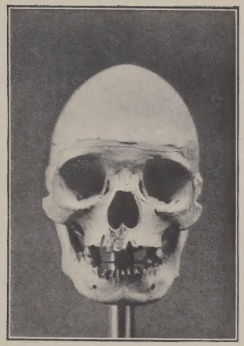

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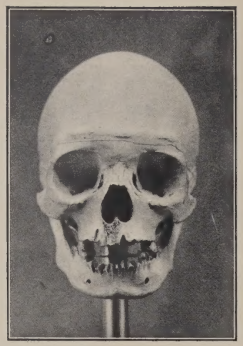

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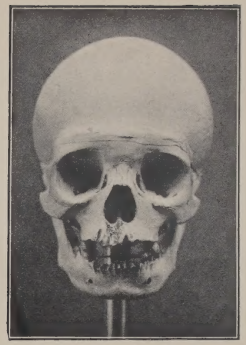

Fig. 1. C.

Fig. 2. A.

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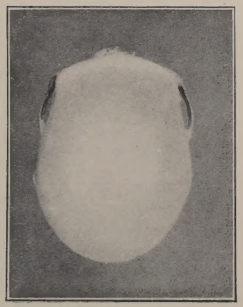
Fig. 2. C.



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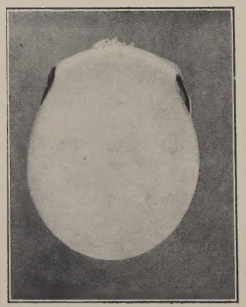

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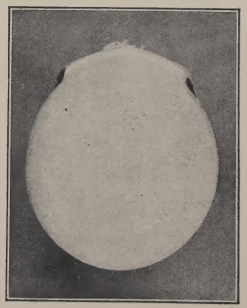

Fig. 3. C.

IN THE ABOVE FIGURES A SKULL IS SHOWN, THE VAULT OF WHICH HAS BEEN REPLACED BY AN ELASTIC BLADDER; THIS HAS BEEN DISTENDED BY THE INJECTION OF VARYING AMOUNTS OF AIR, AND THE RESULTS OBTAINED DISPLAY NOT ONLY A CHANGE IN SIZE, BUT ALSO AN ALTERATION IN SHAPE COMPARABLE TO THE FORMS CHARACTERISTIC OF CERTAIN TYPES OF CRANIA.—THE NORMA FRONTALIS IS REPRESENTED IN FIGS. 1; THE NORMA LATERALIS IS REPRESENTED IN FIGS. 2; THE NORMA VERTICALIS IS REPRESENTED IN FIGS. 3.—IN EACH SERIES THE APPEARANCE OF THE SKULL IS SHOWN WHEN THE BLADDER IS (A) SLIGHTLY, (B) MODERATELY, AND (C) CONSIDERABLY DISTENDED.

ON MAN'S CRANIAL FORM

WHEN first I undertook the delivery of this address I was uncertain with which particular part of my subject I should deal. For this reason I was led to select a title which would afford me the opportunity of varying the details of the matter I might possibly discuss.

There is no lack of interest or variety in the science which I have the honour to represent. The difficulty consists, rather, in the choice of such an aspect of this particular branch of knowledge as may appeal alike to those who are specialists and those whose interests are less technical, for I am anxious to lay stress upon the fact that even the busy practitioner may render immense service to science, if only he will accurately record the observations which often he alone has the opportunity of making.

I have no wish to delay you with a detailed reference to the history of medicine, but I may perhaps be permitted to point out that science owes much to medicine. It was Erasmus who described theology as the mother of the sciences. This may be true as regards the philosophies, but it can hardly be considered applicable so far as the natural sciences are concerned. When we remember how closely blended, in the past, were the interests of the Healing Art with those of Anatomy, Physiology, Botany, Chemistry, and Physics, we recognize how much each owes the other, and how much the cultured physician of the time was of necessity an authority on, and oftentimes an exponent of, these several branches of study. With the acquisition of knowledge, however, and the vast accumulation of new facts and theories, it became no longer possible for one man to attain proficiency in his calling and at the same time maintain a position as an authority on all, or even one, of these kindred studies. In consequence, we

find that this state of things early led to specialism, and so, in course of time, these sciences became severed from and developed apart from medicine.

Of the more recent of the offspring of medicine we may cite Bacteriology and Anthropology.

It is of Anthropology that I wish more particularly to speak; somewhat of a weakling, it may be regarded as the adopted child of medicine, a child possessing no very marked individuality, but displaying traits of character which certainly render it attractive. Its many-sidedness is the source of its weakness and the explanation of its lack of independence. It is little wonder, then, that it should have fallen to the lot of medicine to lend a helping hand to assist it through years of adolescence. Its growth is slow rather than feeble, and every decade marks a record of sure and steady progress.

It may not be amiss to consider for a moment why anthropology, in its physical aspect, should have fallen under the protection of medicine. Its processes and developments concern themselves with all that appertains to man, and no class is better qualified to assist in the solution of its problems than the profession whose lot in life brings it perhaps most intimately in contact with man in his different conditions and environments.

A skilled observer by education and training, the doctor in the performance of his duties is brought into relation with aspects of human nature denied to most others. A pioneer as much as the missionary, he is ever in the front rank, seeking to soften by the exercise of his art the harsher visitations of nature. His work and eagerness for information often lead him into regions hitherto unexplored, whilst his skill in the relief of suffering usually enables him to win the confidence of those who have profited by his assistance. Thus he has opportunities of studying man which the zoologist or the lay explorer can never rival. But although I have laid stress on that aspect of his work which leads him far afield, along untrodden paths, I would have you bear in mind that even in the more familiar walks of life there is much for him to do. He is the constant witness of the ever-varying

influences of nature, operative from birth through adolescence to old age and death. The examination of his patients provides him with opportunities for studying their bodily characters and peculiarities in a manner unavailable to others; whilst his observations on disease, nutrition, food, soil, and climate enable him to form an especially valuable estimate of the influence of environment on the individual and on the community. In matters of heredity, too, his experience often ranges through three and sometimes four generations. For all these reasons the medical man is especially well qualified to play an important part in the development of physical anthropology. He has done so in the past, and there is every reason to hope that he may continue to do so in the future. What is wanted is more co-operation and greater unity of purpose. Whilst individual observations are always valuable, some attempt should be made to combine in research. Just as nowadays the inquiries into cancer and tuberculosis are being conducted in a systematic manner, so many of the problems of anthropology can only be solved by united effort. I am aware that various attempts have been made in this direction, but the great mass of the profession has never been approached to share in the work. I cannot help thinking that if medical men in various parts of the world were requested to furnish such data as were wanted, by a duly elected and properly constituted central authority, much useful information would be acquired, whilst it would lend an added interest to the professional duties of those who helped. The appointment of an international committee of experts would be the first step toward the realization of such a scheme. Were any such plan adopted, it seems to me imperative that those whose co-operation is sought should be instructed regarding the relation to the inquiry of the facts they are requested to record. In this way you are more likely to obtain satisfactory results than if you merely propound questions and expect answers.

I may perhaps best illustrate my meaning by taking a somewhat detailed example. It is natural that I should select a branch of the subject to which I have been lately devoting

considerable attention, and whilst I would by no means presume to hint that it is of all others the most important, yet it will serve to enable me to point out lines of inquiry which may with profit be pursued by those who are actually brought in contact professionally with peoples of different nationality and race.

The subject I propose with your permission to discuss is the vexed question of cranial form and the significance of the cephalic index. I know full well that the matter has engaged the attention of many more competent than I. Yet I think there are aspects of the question which have been overlooked, or at least insufficiently commented on, and that must be my excuse for venturing to address you on what at first sight seems a threadbare topic.

For purposes of convenience, it may be well to group the influences at work in the determination of cranial form under two heads:

(*a*) Those operative from within.

(*b*) Those operative from without.

The former includes such factors as volume of brain, growth of sutures, and ossification of bones, compensation as to balance of head, heredity and breeding. The latter embraces muscular influence dependent on jaw development more or less intimately related to the size of the teeth, and consequently associated with diet. In this way environment plays a part in the modification of man's cranial form in the same manner as it is productive of the variety of shapes met with in other types.

I propose to deal with the mechanical influences enumerated under (*b*) first, because I shall have most to say on this subject, and because, if novelty there be in any of my observations, it is mainly concerned with this aspect of the question.

The time at my disposal is so short that I can only touch very briefly on some of the points which require consideration.

In regard to the teeth, it is obvious that large teeth must require large jaws. Abundant proof has been furnished by Flower and others that the races of mankind display remarkable variety as regards the size of their teeth. Large teeth

are characteristic of the lower races, whilst small teeth are the attribute of the more highly civilized types. Apart, however, from the size of the teeth, testimony is not lacking to prove that a reduction in their number is also taking place. The tendency for the wisdom molar to disappear is much more common in the higher than in the lower races, and when we remember that examples are not wanting of jaws in which a fourth molar has been present on each side, there appears ample justification for the assumption that a reduction in the number of molars has already taken place and is still in progress. But it is not only the wisdom teeth which occasionally fail to appear, the lateral incisors also in some cases abort or are never developed. If then the number, as well as the size of the teeth, is undergoing a reduction, it cannot but be doubted that this must be accompanied by a diminution in the size of the jaws. Other reasons have been assigned to explain the development of the mandible, such as its use for prehensile purposes, its growth in association with the tongue, and the changes induced by the altered conditions of the circulation referred to by Fauvelle [1], but none of these need seriously affect the issue, since none can compare in potency with the influence exercised by the teeth. This is perhaps best illustrated in the case of the apes during the period of the eruption of the permanent dentition, when as Hüter [2] has pointed out, a great increase must necessarily take place in the molar segment of the body of the mandible to provide accommodation for those teeth which are not represented in the milk dentition. The changes which are so characteristic of the apes one would naturally expect to see displayed in the case of man, but here, unfortunately, the evidence is somewhat conflicting. Pruner Bey held that at birth the negro child displayed no prognathism, whilst Hrdlicka asserts that the face of coloured children is generally more prognathic than that of white. Here, then, is an instance of the necessity for further information.

Although we accept it as correct that large teeth necessarily

[1] *Bull. de la Soc. d'Anth. de Paris* (1888), p. 463.
[2] *Virchow's Archiv*, Bd. xxix. p. 21.

require large jaws, it by no means follows that the jaws are more projecting. A moment's consideration will enable you to realize that, given an equal alveolar length, two jaws may display quite different appearances: in one the curve may be of the parabolic type with consequent projection, in the other it may assume an elliptical form with less forward thrust. In one the jaw will be associated with a narrow, in the other with a broad face.

But whilst we have seen that the jaws are liable to many varieties of size and shape due to alterations in the number and magnitude of the teeth, we must also consider what effects these changes will have on the development of the muscles connected with the mandible.

The extent and development of these muscles lead to many variations in the form and extent of the temporal fossae, to mention only one instance of muscular attachment: and no one who has examined a series of mammalian or avian skulls but must have been struck by the remarkable modifications in the cranial shape induced by a greater or less development of the muscles of the jaws or beak.

As Dr. Keith, to whom I am indebted in this inquiry for much valuable assistance, has pointed out, the expansion of the temporal area over the side of the skull in the anthropoids is correlated with the developing jaw and the eruption of the permanent teeth. In this group of animals the changes induced are very manifest, because the results are not masked by undue expansion of the cranial cavity. In the anthropoids the average cubic capacity of the adult exceeds that of the young animal by from 50 to 150 c.c., whilst in man the difference between the cubic capacity of infants a few days old and children of fifteen years of age amounts to 978 c.c. (Topinand). As we shall see hereafter this expansion reacts on the influence of the temporal muscles.

Whilst these facts have been widely recognized and their influence more or less directly referred to, so far as I am aware no attempt has been made to estimate their value as determining factors in the production of cranial form. Nor need we be surprised at this, since the methods of mensuration

of the lower jaw now apparently universally adopted by Craniometrists is one altogether useless to enable us to analyse the mechanism of the jaw and its muscles. The only paper to my knowledge dealing with the lever-like action of the jaw is one by J. Gorham[1]. In this, however, the author was concerned with the arrangement and form of the teeth as set in the jaw, and the forces necessary to raise them. In the present instance we are concerned not so much with the forces exercised on the jaw, but rather with their secondary effects on the parts from which they arise.

The width between the condyles of the jaw is, necessarily, correlated with the width of the cranial base. The condylo-symphysial length, which is the measure of the distance between two verticals passing in front of the symphysis and behind the condyles, whilst the jaw rests by its body on a horizontal plane, will indicate pretty precisely the long arm of the lever. By comparing this length with the intercondylic width = 100, we get what, for convenience, may be termed the mandibular index.

$$\frac{\text{Condylo-symphysial length} \times 100}{\text{Intercondylic width}} = \text{Mandibular index.}$$

I find this index ranges from 70 to 100: when the index is high it means that the jaw is long proportionately to its width, whilst when the index is low the jaw is short, relatively to its width. Grouping together my results it appears that thirteen brachycephalic skulls yield an average mandibular index of 84·8, eleven mesaticephalic skulls an average of 88·8, whilst twenty dolichocephalic skulls yield a mandibular index of 90·6. There is thus distinct proof of a correlation between jaw-length and head-length.

Discarding for the time being the influence of the other muscles closing the jaw, and confining our attention to the temporals only, it is obvious that a long jaw will require a more powerful muscle than a short jaw to produce the same result at the 'bite,' provided the force is applied at the same distance from the fulcrum. Were such the case, the

[1] *Medical Times and Gazette* (1875), vol. i. p. 28.

problem would be fairly easy, but, unfortunately, nature provides compensation by varying the position of the point of application of the force. Assuming that the tip of the coronoid process represents the point of maximum intensity of the power exercised by the temporal muscle, we find that the distance of that point from the axis of rotation of the temporo-maxillary articulation varies considerably in individual jaws.

The length of the short arm of the lever may be somewhat roughly estimated by measuring the distance between the posterior edge of the condyle and the tip of the coronoid process. Reducing this to its proportion to the length of the mandible (condylo-symphysial length) we can obtain an index thus:—

$$\frac{\text{Condylo-coronoid width} \times 100}{\text{Condylo-symphysial length}} = \text{Coronoid index.}$$

This enables us to determine the proportion of the short arm of the lever to the length of the long arm. I find from comparison of the specimens I have examined that this index ranges from 43 to 31. That is to say, assuming that the force is applied at right angles to the lever and also that the coronoid process always lies in the same horizontal plane as the lever, the jaw with a high coronoid index will act, provided the same force be applied, with proportionately greater advantage than one with a low coronoid index; for in the case of the jaw with a high index the force is applied at a point further removed from the fulcrum than in a mandible with a low index. In estimating the amount of force necessary to effect the same result in the masticatory apparatus of two skulls, we have these two factors to consider: first, the length of the lever or jaw as a whole; and second, the disposition of the force on that lever. The subject thus becomes much more complicated than before, for an examination of a considerable number of specimens proves that these two factors do not always interact upon each other in the same way. Thus we may have a long mandible which will obviously require the exercise of greater muscular force to discharge its functions, were it not that this is compensated for by the fact that that

force is applied at a point more remote from the fulcrum. On the other hand a jaw of similar proportions, owing to the fact that the coronoid process lies closer to the condyle, will require a much greater muscular effort to produce the same result.

There seems to be a correlation between the coronoid index and the cephalic index, for I find that the higher coronoid index is more usually associated with dolichocephaly, whilst the lower coronoid indices are met with in skulls of the brachycephalic type. The number of observations, however, is too few to draw any conclusions from, and further data are required before we can arrive at any definite result.

Since, then, it appears that we are unable to harmonize the counteracting influences of the two factors at work, it occurred to me that perhaps the best way to attempt the solution of the question would be to determine experimentally the amount of force necessary to overcome the same amount of resistance in jaws from different skulls the measures of which (the skulls) were known. As the reader will understand, my object in thus studying the mandible has been to attempt to estimate in each particular skull the amount of force exercised by the temporal muscle to produce a like result. Were we successful in doing this we should be able to form some idea of the relative developments of the temporal muscles, and thus see whether, as I have already hinted, this development of the muscles has any correlation with the cephalic index, and if that be so, whether we are justified in regarding it as one of the predisposing causes in cranial formation. For this purpose I devised an apparatus, details of which are published elsewhere, which enabled me to estimate with fair accuracy the amount of force necessary to overcome a similar resistance applied over the incisor teeth of the jaws I experimented with. Thus I found that the weights necessary to act as a counterpoise to the jaw loaded with 100 grammes placed over the incisor teeth or at the 'bite,' ranged from 320 to 448 grammes. In other words, assuming that we closed the jaws with a force equal to 100 grammes at the incisor teeth, we should require to exercise a muscular effort equal to from

320 to 448 grammes. And if at the same time we neglect the influence exerted by the other elevators of the jaw, we may regard this as some index of the development of the temporal muscles. Such being admitted, it must also be obvious that a corresponding force will be exerted over the area from which the muscle arises. Granting that this be so, we should naturally expect a correlation between the weights recorded and the cranial form, assuming of course that we are prepared to admit that the shape of the head can be affected by any such influences.

Happily for my argument, we find this view abundantly supported, for whilst the brachycephalic skulls average a weight of 370 grammes to counterpoise their jaws loaded to the extent of 100 grammes, we find the dolichocephalic skulls require a weight of 390 grammes to produce a like result under similar conditions—that is to say, a difference of over 5 per cent. in the amount of force necessary to produce the same effect in the two types. Now when we consider the large amount of force a healthy man can exert by closing his jaws, it will be at once recognized that the amount of effort necessary to produce this result will vary very greatly; in other words, that the dolichocephals are, as a rule, furnished with more powerful temporal muscles than the brachycephals, and further, since we have already shown that the mandible of the long-headed races is more projecting than that of the round heads, we are justified in assuming that this increased muscularity is necessary to overcome the mechanical disadvantage at which so long a lever acts.

I will not dwell on this aspect of the question further than to remind you that the sides of the cranial vault to which the temporal muscles are attached are the parts of the cranium which are most intersected by sutures of a complicated arrangement. We can therefore readily understand how this, the region of the pterion, is less able to withstand long-continued pressure, or perhaps it would be better to describe it, as that it is more susceptible to the influence of prolonged stress.

Passing now to the consideration of the causes operative

from within, I need say nothing of the influence of sutural growth except to refer to the recent work of Papillault[1], who has shown that the occurrence of the metopic suture is more common among races with large cranial capacity, and is due to a superiority in the bulk and relative weight of the cerebrum.

What I would particularly like to lay stress upon are the observations of Boas[2] in regard to the cephalic index. That distinguished anthropologist has succeeded in establishing certain correlations which are most valuable. Thus he shows that the diameters of the skull are primarily determined by its capacity, the height appears to be most closely associated with the capacity, the length least so. On the other hand the correlation between the breadth of the face and the horizontal diameters of the head shows the two transversal diameters to be very closely correlated, while the length of the head is more closely correlated with the height of the face. Boas further states that when capacity is introduced into our consideration of the question a compensatory growth is found to exist between the breadth of the head on the one hand and height and length on the other. 'The relation between capacity and head diameters is found to be of fundamental importance, and among these, the relation between the transverse diameter and the capacity is most significant.'

Failing the time to refer to other considerations of interest in this connexion I must content myself with drawing your attention to the confirmation these views receive from those classes of pathological cases in which there is either a diminution or an excess in the volume of the cranial contents. I refer to microcephaly and megacephaly of a hydrocephalic type. The ape-like characters of the former have frequently been referred to, whilst the 'old-fashioned' or intellectual appearance of sufferers at an early stage of the latter disease has often been remarked upon. For our purpose it is important to note that these appearances are entirely dependent on cranial capacity. The microcephal is usually

[1] *Mém. de la Soc. d'Anth. de Paris*, tome ii, 3e sér., 1er fas.
[2] 'The Cephalic Index.' *American Anthropologist*. N. S., vol. i (1899), p. 448.

a pronounced dolichocephal of a simian type, whilst the chronic hydrocephal usually displays the appearance of exaggerated brachycephaly. Perhaps one of the most interesting points in connexion with both these classes of cases is that while the cranial vault, i. e. that part of the calvaria developed in membrane, displays great variation in form and size, the cranial base, i. e. that part of the skull ossified in cartilage, shows little evidence as a rule of much alteration of its relative proportions.

It seems we have thus an explanation of how by increase in the volume of its contents the cranial capacity can not only be enlarged, but the shape of the cranial envelope modified. One might have expected to have obtained confirmatory evidence of these views by noting the changes which occur in the form of the head attendant on its increase in capacity during growth. The evidence adduced, however, is very conflicting; whereas some observers maintain that, as the child grows, its head increases to a proportionately greater extent in the transverse diameters, others assert that increased relative length is the rule. Both are probably right, and the discrepancy between them is due to the fact that their observations have been made on different types, types in which the various factors interact differently so as to produce different results. Here we have an admirable instance of the kind of information much desired and surely readily obtainable, if only the want were proclaimed. It is highly probable that a negro child's head is much rounder than it is in the adult, in this respect resembling the anthropoids, whilst the head of a white infant is probably more elongated than it is in after life. The changes being due entirely to differences in cranial capacity and the influence of the masticatory apparatus. Until such evidence is forthcoming, however, it would be rash to venture upon any conclusions.

Considering the membranous nature of the cranial vault during growth and development, as contrasted with the cartilaginous base, it stands to reason that the vault will be reacted on more readily than the base; and given a cavity

of oval or elliptical form with elastic walls, the more its contents are increased the greater will be the tendency to assume a spherical shape.

That man is descended from a pronounced dolichocephalic type with a cranial capacity lower than that of any existing race is generally conceded; it follows that the modifications in shape consequent on an increase in the volume of the brain will tend toward sphericity; in other words, the cranium will become rounder. All the evidence seems to point this way, and although there may be some who doubt the validity of such an argument, they will, I trust, be convinced with the proof I now propose to supply.

It occurred to me that it might be possible experimentally to test the influence on the form of the skulls of those mechanical agencies which we have just discussed. This I have done, in the models which I show you. In these, the vault and sides of the cranium have been cut away, leaving only the base. To this has been cemented a rubber bladder which can be inflated through a tube passing through the foramen magnum. To the sides of this bladder have been cemented a number of silken cords arranged as are the fibres of the temporal muscles. By affixing weights to these, or by putting a strain on them, we can exert an influence over the area of the bladder to which they are attached, comparable to that which the temporal muscles exercise on the cranial walls. We are thus provided with a means of testing the changes induced by increased capacity, for by altering the degree of this tension of the bladder we can simulate pretty closely the natural process. We can further test the influence exerted by the temporals by putting a strain on the fibres of the imitation muscles in the model. Let me now proceed to demonstrate what takes place in these models under different conditions. I have one model here in which the temporal muscles are not represented. On this we can test the influence of increasing distension on the cranial envelope. With just such an amount of air within the bladder as is necessary to slightly distend the walls we obtain a form which is distinctly reminiscent of the anthropoid apes. The

internal pressure is not yet sufficient to distend the forepart of the cavity, and in consequence the brow ridges remain prominent and outstanding, whilst the shape assumed by the vault is that of pronounced dolichocephaly. On increasing the internal pressure by the injection of more air, the frontal region becomes gradually inflated, with consequent gradual disappearance of the prominent supraorbital arches. In fact, as the internal tension is increased, the envelope alters so as to display successively the contours associated with such types as that of Pithecanthropus and the skulls of the Neanderthaloid and Australoid races. As yet, however, the vault preserves its elongated and narrow form, thus exhibiting in almost every detail the characteristics of the skulls of what may be termed the primitive races of man. On proceeding still further with the inflation of the balloon, the expansion, whilst general throughout, particularly affects the height and width of the vault, passing through all the stages of decreasing dolichocephaly, through mesaticephaly to pronounced brachycephaly. The consequent elevation of the frontal region at length causes the entire obliteration of the projecting brows, and the appearance presented by the model displays all the features of a skull of elevated type.

It may be argued that the foregoing experiment proves nothing, yet whilst admitting that the means employed are only a crude imitation of Nature's processes, it must be conceded that the model displays in a very striking manner the appearances exhibited by skulls of different types.

The cause of the production of the supraorbital ridges and their subsequent disappearance by the further distension of the cranial cavity is most instructive. We see now the necessity for the massing of the bone in this region in skulls of small cranial capacity. The cranio-facial axis is as essential to the face as it is to the calvaria. For a reduction in the size of the latter does not necessarily reduce the length of that base from which the skeleton of the face depends.

As a consequence, however, of the reduction of the size of the cranial cavity, the bone over the orbital ridges must be thickened in order to afford a base of resistance, through the

superior maxilla, against the bite of the mandible. When, however, the distension of the cranial cavity leads to an expansion of that space over the orbits and a consequent elevation of the frontal region, the necessity for this heaping up of the bone over the brows disappears, since the orbital and ascending plates of the frontal bone are now disposed at such an angle as to enhance greatly the strength of this part of the skull without entailing so much bony deposit.

The experiment further demonstrates the gradual transition from the dolichocephalic to the brachycephalic form which accompanies increased cranial expansion. It seems absurd, after this exhibition of the influence of internal pressure, to discuss the independent origin of the dolichocephalic and brachycephalic types. Everything points to the dolichocephalic as being the older stock, and though it may have taken many thousands of years to have evolved the rounder-headed races, we have only to consider the evidence adduced in connexion with hydrocephaly, and the facts demonstrated in the above experiment, to realize how readily this transformation may occur, and how intimately it is associated with increased internal capacity.

Whilst undoubtedly the influence of capacity is of paramount importance in man, we can study in the models the modifying influence of the temporal muscles by exercising a certain amount of traction on the silken fibres which represent these structures. This is best done by the application of weights, and, as the results show, considerable alterations are thereby effected. As will be seen, the effect produced varies with the degree of distension of the capsule and the amount of weight employed, and whilst the results are not so striking as might be expected, still they are sufficient to prove that they must be taken into account in considering the varieties and subtilties of cranial form to which, of late, Sergi has directed special attention. Further, as will be seen, the results differ accordingly as different parts of the muscles contract (as represented by the tension exercised on the silken cords). Now an examination of skulls of different types clearly demonstrates the fact that the expansion of the area

of attachment of the temporal muscles does not always take place in the same direction. Some tend to rise on the side of the cranium, whilst others spread further backward. In this connexion there seems reason to believe that the posterior fibres of the muscle are better developed in those who use their jaws in a grinding fashion, and probably this is correlated with the wear of the teeth so characteristic of certain races. No doubt the tough and gritty nature of their diet may to some extent explain the attrition of the teeth in certain races, but it would also be a direct cause of the more powerful grinding movements necessary to reduce the food to pulp, thereby increasing that part of the muscle more particularly concerned in the grinding movement. Be that as it may, the fact remains that, when in the model the capsule has been distended so as to assume an ovoid form, an increased traction of these posterior fibres at once converts the shape into that of an ellipsoid.

The time at my disposal has prevented me from touching on many subsidiary details of no little importance, nor have I been able in this general survey to refer, in even a general way, to the researches of others. My endeavour has been rather to prove that the shape of man's head in his higher developments is the outcome of those physical and intellectual environments which have led, on the one hand, to the reduction in size of his jaws, and on the other, to the increased volume of his brain. These attributes are perpetuated by the influence of heredity and modified by cross-breeding and the laws of natural and sexual selection, but there is no constancy about them. Primarily they are dependent upon the physical forces which we have just discussed.

We have, I trust, been able to trace the gradual ascent in the form of man's cranium from one group to the other; thus disposing of the necessity of explaining the existence of the dolichocephalic and brachycephalic types as due to independent origins. Furthermore, I have endeavoured to show how the confirmation of this solution of the problem of man's varied cranial form can be assisted by the careful and accurate records of those in practice, who have opportunities of noting

the changes in jaw form and head shape during the periods of growth from infancy to maturity.

In conclusion, let me say that, as regards the cephalic index, I am in entire agreement with Professor Boas, who considers that whilst that index ' is a convenient practical expression of the form of the head, it does not express any *important anatomical* relation.' My own observations entirely confirm his view that the relation between capacity and head diameters is of fundamental importance, and that among these the relation between the transverse diameter and the capacity is the most significant.